ECONOMIC CONSIDERATION AND ENERGY POTENTIAL OF AGRICULTURAL WASTES

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Introduction

Bio-Gas of Colorado has been doing business as a company for two years dealing with treatment and reuse of agriculture waste organic materials.

We believe a commercially viable energy from the agricultural waste conversion industry potentially exists. This paper attempts to illustrate this statement.

Our research and studies have been conducted in Colorado, Arizona, Utah and New Mexico in conjunction with grants from the 4-Corners Regional Commission. Much of our design information has been accumulated from pilot plant operations and studies at the Monfort of Colorado Inc. beef feedlots. However, the information presented in this paper deals with Colorado exclusively.

Background

Agriculture waste material such as steer manure has an energy value which ranges from 3000-8000 BTU per pound of solid material. This material currently is being used, almost exclusively, in its traditional manner as an addition to agricultural croplands. Various processes, well known and reported, are available to convert this manure into a form of energy product such as oil or gas.

The most often reported processes are:

1.) direct combustion
2.) pyrolytic conversion
3.) anaerobic digestion

Our studies have been exclusively concerned with the process of anaerobic digestion for reasons which will be discussed later.

Definition

First, we'll discuss what we consider would be agricultural wastes of an energy producing nature. Specifically we have defined agriculture wastes as:

1.) Residue from animal husbandry operations
2.) Food processing wastes
3.) Crop residue left in the fields (or collected)

These materials are all generated in large quantities. Items one and two are in a reasonably centralized or collected form and are generated on a continuous basis. Item three is neither generated continuously or normally collected.

In Colorado, crop residues are not removed from the fields and most agriculture state agents strongly recommend leaving this material on the fields for erosion control in the windy climate.

Amounts

Anderson(1) estimates 194.5 million tons of moisture and ash free organic material from animal husbandry operations are generated yearly in the U. S.

Burford (2) estimates that 1,065,500 tons per year of dry organic material (volatile solids) are collectable from 17 areas of concentrated livestock feeding in Colorado. The maximum distance considered for transporting manure was 15 miles. This information was generated during the summer of 1975 and represents approximately 52% utilization of the state feedlot capacity.

In Colorado, 8 areas or potential sites have been located in which the quantity of manure generated is large enough to justify a utility size methane facility.

Available Energy

Before going into the amount of "deliverable" product such manure could generate, a discussion of the conversion process and the state of the "delivered" feedstock is in order.

Manure, as delivered, from an open dirt feedlot (found in Colorado or in the southwest in general) would be extremely variable in a) moisure content, b) dirt or grit ratio and c) extent of decomposition caused by exposure during the confinement period. Figure 1 shows decomposition and organic carbon loss in a typical manure sample versus exposure time. Figure 2 shows a typical steer manure as received per ton breakdown.

As mentioned earlier, our work has been exclusively devoted to the utilization of anaerobic digestion to process the manure. Manure as a "fuel" must be processed before direct combustion or pyrolytic decomposition could be practical. Anaerobic digestion however, would be less affected by moisture content, being a process whereby dilution with water is accomplished before utilization. Dilution allows the grit to be removed by simple sedimentation. The energy loss is less due to the water content than in other mentioned processes.

However, the main reason that digestion is viewed by the authors as the <u>only</u> viable process for utilizing the energy value of the manure is that the process allows the nutrient and humus values of the manure to be available to the farm community. Any process which destroyed nutrient and humus value of manure would be found in much disfavor by the agriculture community.

Anaerobic digestion is a process which utilizes bacteria to decompose (ferment) the organic fraction of the waste material.

The bacterial action is a complex process and a discussion of bacteria fermentation is neither the intent of this paper or practical in the time allowed, however, for those interested, a bibliography of excellent sources for this discussion is included in the reference section of this report. (3, 4, 5, 6)

Basically the following items are of importance in the efficient bacterial decomposition of organic material.

1.) Oxygen free environment - Those bacteria known as methanogenic bacteria are strict anaerobes and cease functioning in the presence of oxygen. This requires sealed tankage.

2.) Proper digestion time- The bacteria function at a rate proportional to temperature between 60-110°F (15.56-43.33°C) Mesophilic range, and 120-150°F (48.89-65.56°C) Thermophilic range.

At any given temperature enough time (minimum digestor tank volume) must be provided to allow the methanogenic bacteria to properly process the organic material. A minimum time of 10 days is required at the Mesophilic temperature of 98°F, and 4.75 ft^3 of methane is generated for every pound of organic matter introduced into the system.

3.) Temperature uniformity - Although digestion will proceed at any of the temperatures mentioned, temperature changes greater than ± 2°F in any 24 hour period are enough to cause "temperature shock", a phenomena whereby the bacteria become relatively dormant and gas production ceases. This requires a temperature control system and insulation of the digestion vessel.

4.) Nutritionally balanced feedstock - The bacteria require basically, organic carbon (lignin or non-organic forms of carbon will not digest), nitrogen, phosphorous and trace elements. Manure has enough of all the nutrients required. Increases in organic carbon alone could be tolerated with a resulting increase in gas production.

5.) Absence of toxic elements - Heavy metals and ionic material of high concentration can cause bacteria to cease functioning.

When the proper conditions are provided, the bacterial action can take place and the process of degradation or fermentation can take place.

The gas released from the process is known as bio-gas and roughly consists of 50%-70% CH_4, 30% CO_2 and a trace of H_2S by volume.

Our pilot plant consistently produced a gas of 55% CH_4 by volume (at Denver altitude) and verified that 4.75 ft^3 of CH_4 could be generated for every pound of organic matter.*

Process Consideration

Figure 3 shows a basic flow schematic as proposed for the Monfort Gilcrest feedlot. This facility is sized to handle 100,000 cattle units of manure input. (A cattle unit is 1 animal of 1000 lbs weight). Again a complete description of the process (one of many proposed) is beyond the scope of this report but basically, the feed-manure is:

1.) mixed with water,
2.) sand and grit removed,
3.) the resulting slurry is heated and
4.) introduced into digestion vessels where digestion occurs.
5.) Bio-gas removed, H_2S and CO_2 removed, compressed and sent into the interstate pipeline.
6.) Residue removed from digestion vessels, solids separated, remaining liquid is admitted to aeration basin.
7.) The liquid is aerated allowing aerobic bacteria to grow.
8.) Solids again separated and the remaining liquid remixed with manure.

Plant Performance

A 100,000 cattle unit facility would input 1,200,000 lbs of dry solids per day to the plant. The plant will use 4 digestor vessels of 1,000,000 ft^3 capacity each to provide the required detention time for bacterial action. Methane generated would be 3,406,000 ft^3/day, at a cost of \$1.60 - \$2.00/1000 ft^3. The bio-gas would be cleaned to the extent necessary and compressed to a pipeline pressure of 850 psig for sale.

Digestor Heating

Judicious use of insulation and heat exchange are required in the process to keep the net energy requirements as low as possible. A coal fired boiler will provide a majority of the net digestor heating requirement. Augmenting heat sources will be waste heat of compression and solar energy. A form of flat plate collector using digestor effluent as the heating medium has been patented and incorporated into the system design.

Capital Costs

Bio-Gas of Colorado has been engineering on this facility for 2 years and our latest capital cost estimate shows a \$5,500,000 - \$6,500,000 cost for this facility. (\$1,610 - \$1,910 capital cost per generated MCF) Figures 4 and 5 show capital cost figures for digestion systems of various sizes as explained on each figure.

* On a theoretical basis the breakdown of 1 lb of cellulose would yield 7 ft^3 of methane. 4.75 ft^3 is an actual yield.

We have built several of the smaller sizes as shown on figure 4, and these figures include 40% markup over cost for the builders.

Figure 5 is estimated and assumes costs as related to an owner-operator, however, IDC and contingency of 15% are allowed in figure 5. As can be seen from 10,000-100,000 cattle units is the least size sensitive area on the curve and 40,000-50,000 cattle units would be required to "make the deal" interesting to anyone contemplating a manure/gas facility.

Some explanation of construction techniques is in order to justify figure 5.

The process flow schematic is relatively simple. The facility consists basically of large tanks and lagoons for holding slurries and allowing anaerobic and aerobic bacteria to process the material feedstock. The physical size of the tanks required to allow the proper hydraulic detention time is the feature which causes the largest increment of capital cost in the envisioned facility. Traditional sewage plant design relies on concrete and/or steel tanks, each custom engineered and field erected.

A factor cost much reported for these municipal installations is $2.00/ft^3 of digestor volume.

In the envisioned facility, all tanks including the digestor vessels themselves, the clarifiers and lagoons are all "Hypalon-lined" in-the-ground-trenches, a type of construction finding favor in more recent waste treatment projects. Use of this type of construction has allowed keeping the total capital costs under $2.00/ft^3 for this type of facility. This includes the extra equipment such as slurry mixing, gas cleaning and compression, and liquid aeration that a municipal facility would not require.

Conclusions

It is our contention that a potentially viable energy producing industry could be operated in Colorado and in other agriculturally oriented states for the following main reasons:

1.) Manure is available in "commercial" quantities in a collected form.
2.) Today manure is available at $2.00/ton or less ($.615 - $.705 million BTU). As a fuel manure today is cheaper than coal.
3.) The technology is well known to convert the energy value of manure into a very desirable form.
4.) It appears the cost of capital for the conversion facility (under $2,000 per generated MCF) is also desirable.

TABLE 1

COLORADO MANURE INVENTORY AND GAS PREDICTION

Per Animal	Cattle	Dairy	Hogs	Sheep	Chickens	Turkeys
Solids Per Animal						
Total dry solids	12.0	13.2	1.12	.5	.073	.20
Percent volatile solids	80%	80%	85%	80%	76%	76%
Volatile solids/day	9.6	10.56	.95	.40	.055	.15
Expected volatile solids scraped per animal/day[1]	7.17	8.44	.76	.32	.055[2]	.12
Methane (CH_4) Potential Animal Basis:						
Livestock in all 17 Site Areas	676,218	36,050	104,000	258,000	1,997,000	3,455,000
Livestock in "Big 8" Site Areas	565,364	22,100	80,000	254,000	1,946,000	3,415,000
Gas potential (MCF CH_4/day)[3] in all Site Areas	23,030	1,445	375	391	522	1,969
Gas potential in "Big 8" Site Areas[4]	19,255	885	289	386	508	1,947
Total Gas Potential						
In all 17 Site Areas		27,733,000 $ft.^3$ per day				
In "Big 8" Site Areas		23,270,000 $ft.^3$ per day				
In "Big 8" with collectable factor applied[5]		21,022,000 $ft.^3$ per day				

[1] This includes a 6% initial volatile solids loss in run-off and 15% loss due to decomposition during the six month cleaning period (average manure age of three months).

[2] Weekly cleaning as opposed to deep pit operation.

[3] Methane (CH_4) production per pound of volatile solids equals 4.75 $ft.^3$ per pound.

[4] Sites 1, 5, 6, 7, 8, 9, 12, 14.

[5] Cattle, 100% manure from lots 1,000 head or greater, 60% from lots less than 1,000 head; 60% fron Dairy waste; 50% from Hog, Sheep, Chicken, and Turkey operations is collectable.

FIGURE 1

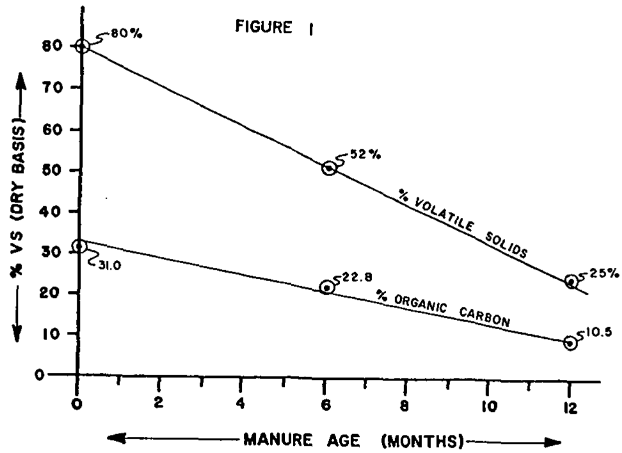


FIGURE 2

PLANT INPUT & OUTPUT

ON UNIT WET TON BASIS

- Expected manure scraped ⟶ 4.0 Ton per head per year

- Input - Output:

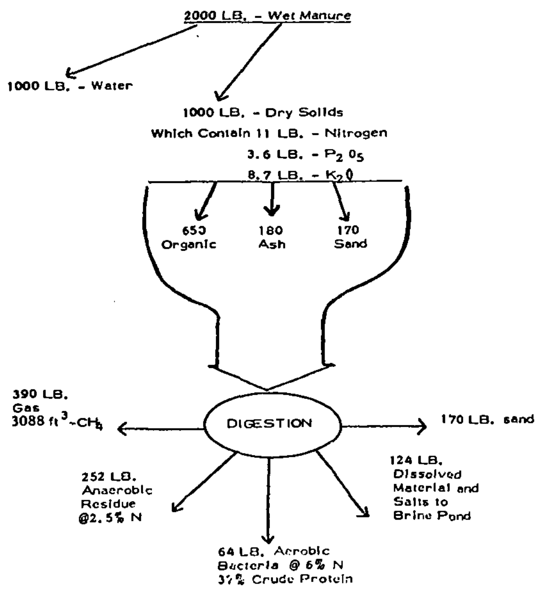
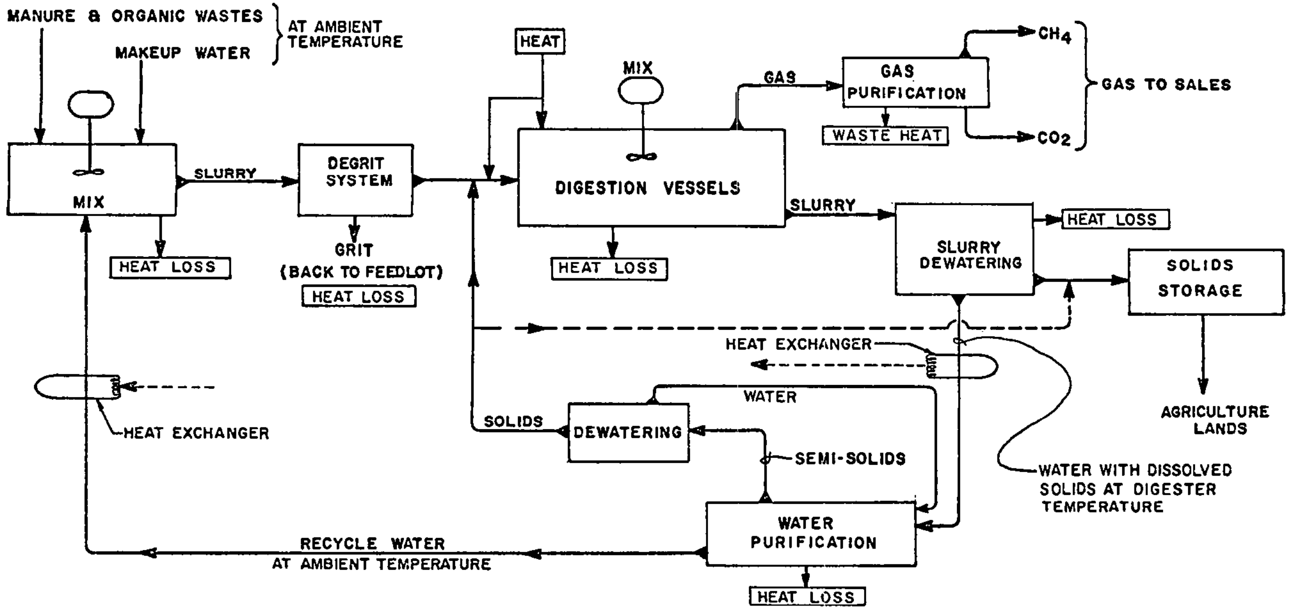


FIGURE 3



MAJOR BLOCK DIAGRAM

AGRICULTURE WASTE/GAS PRODUCTION

FIGURE 4

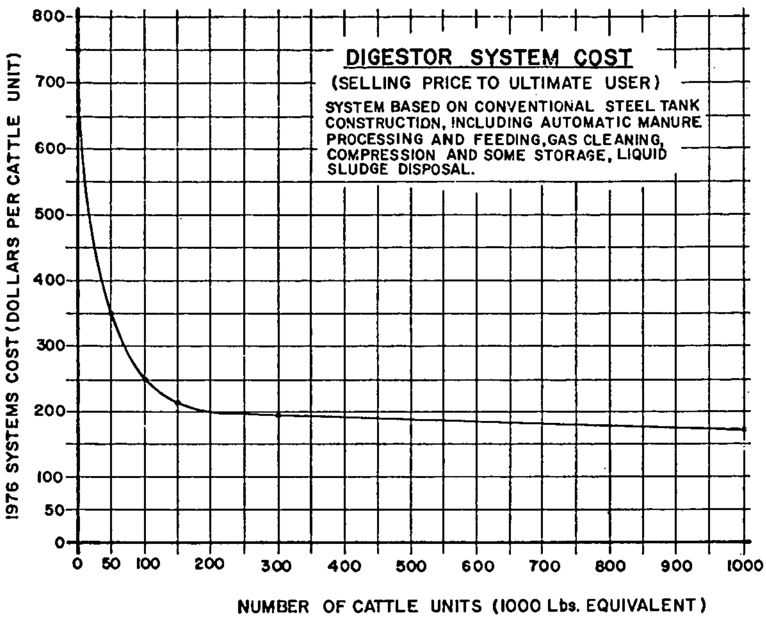
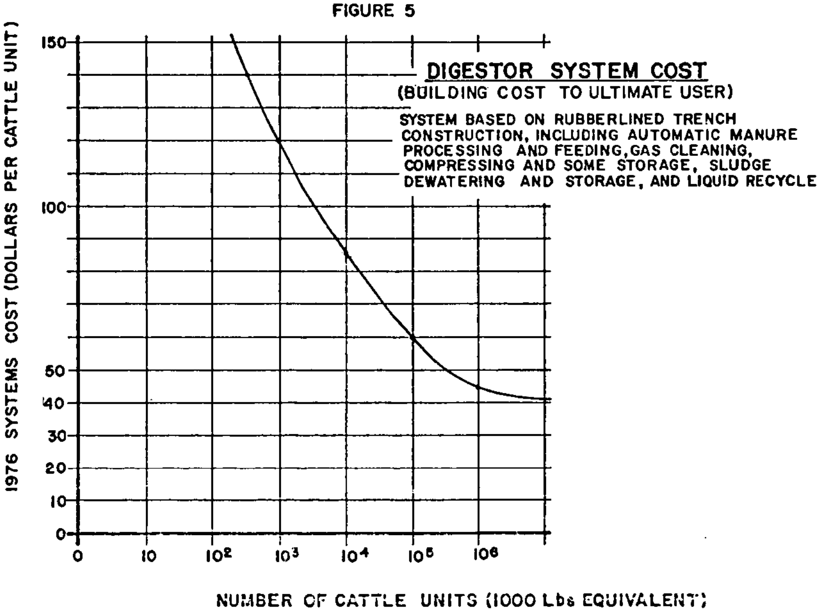


FIGURE 5



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